Critical Angle of Dimer-Monomer Sandpiles

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We measure how strong, localized contact adhesion between grains affects the maximum static stable angle, θ_c, of a dry sandpile. By mixing dimer grains, each consisting of two spheres that have been rigidly bonded together, with simple spherical monomer grains, we create sandpiles that contain strong localized adhesion between a given particle, and at most, one of its neighbors. We find that tan θ_c increases linearly from tan θ_c = 0.45 to tan θ_c = 1.1 as we increase the number fraction of dimer particles, ν_d, from ν_d = 0 to ν_d = 1. This increase in θ_c exists despite a drop in the measured total volume fraction occupied by the grains, ϕ, from $\phi \approx$ 0.58 at ν_d = 0 to $\phi \approx$ 0.52 at ν_d = 1. We attribute the linear increase in tan $\theta_c(\nu_d)$ to the increased immobility of dimers at the surface of the sandpile. This measurement demonstrates that even a small relative fraction of strong, nonuniform adhesive contacts between grains in sandpiles can significantly increase the sandpile's resistance to gravitationally-induced failure.